7 Appendix 1. Richard S. Claassen, "Presentation to MJ Kelley on Fundamental Research at Sandia" (1957)

From: SNL Corporate Archives
Collection # 7, 1100 History of Research
(F. L. Vook) Solid State Science

May 31,

DISTRIBUTION

On March 16, 1957, a presentation was made to M. J. Kelley. It described the plans for "fundamental research" at Sandia. A written form of the presentation by Claassen is attached. His summary of Dr. Kelley's remarks is also included.

Since this program is still in a formative stage, I would appreciate any constructive comments or suggestions on this general subject.

Original signed by
R. S. Claassen

R. S. CLAASSEN - 5133

RSC:frh

Copies to:
G. A. Fowler, 5000
S. C. Hight, 5100
M. L. Merritt, 5110
W. W. Bledsoe, 5120
G. E. Hansche, 5130
A. Y. Pope, 5140

Enc.
(1) CRD memo
(2) Unc. memo

~~TRANSMITTAL~~
~~WHEN SEPARATED FROM ENCLOSURES, HANDLE THIS DOCUMENT~~
~~AS Unclassified~~
~~(INSERT PROPER CLASSIFICATION)~~

~~CONFIDENTIAL~~

UNCLASSIFIED per Declassification Notice dtd 5/20/87 MAR 1 6 1957

INTRODUCTION

I would like to describe for you our plans, desires, and goals for a program in what we call fundamental physical sciences. I would like to do this in four parts, following a little background of material. First, I will try to describe the objectives; that is, those accomplishments which we hope to achieve by such a program; second, what I call the configuration of such a group; third, the method by which we have chosen the fields in which we will work; and fourth, two examples of specific programs which have already been initiated in this area.

Since the term "fundamental" and the term "science" are used in so many ways by different people, perhaps we should define first what we mean by "fundamental physical science". The real definition should be evident by the end of my talk, as determined by the boundary conditions we will place on this program and as exemplified by those programs which we can list. Briefly, however, let me say that by "fundamental physical science" we intend to imply research programs which will contribute new and original knowledge of phenomena in the fields of physics, physical chemistry, and to a lesser extent, electrical engineering and engineering mechanics.

As you are aware, Sandia Corporation has reached its present position as a research and development laboratory by a process of evolution. I believe it is pertinent to point out the relationship of this evolving pattern to our present plans for research activities. Originally, Sandia was a split from Los Alamos Laboratories, fostered mainly by geographic considerations. The primary function to be served was that of matching into the military system, and as time went on, to this was added the problem of production of engineering designs which had been partially completed elsewhere. Still later the increased scope of variety of weapons designs has created a logical need for development

~~RESTRICTED DATA~~

~~This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.~~

UNCLASSIFIED

~~CONFIDENTIAL~~

MAR 1 6 1957

The first objective of this group is that of direct assistance to other individuals in the Corporation. There is an endless variety of circumstances which will bring a technical staff member in the Corporation to the point where he needs advice or information from a specialist in some particular field. We feel that this advice or information is of far greater use to a member of Sandia's engineering staff if it can be obtained from Sandia's own research staff. First of all, there is the matter of convenience and informality. Second, there is a matter of understanding on the part of the specialist of the problems of the Sandia engineer. Third, there is another type of benefit to be gained. The research scientist who is a member of the over-all team of research and development will at times seek ways in which the development engineers or others can achieve better results or reduce their labors for the same end result. This kind of benefit, of course, can be achieved only where the research scientist is working as a member of a team including the development groups, so that he will have continuing access to knowledge of their programs. Perhaps the most important contribution in this first area is that of helping to resolve crises when they arise on the production line, in quality assurance, or elsewhere. A research scientist on our own staff is obviously in the best position to pitch in immediately and help eliminate the problem as rapidly as possible

A second objective for such a group is in the area of new inventions or discoveries. By organizing this group of research individuals as a part of a Corporation, and by proper communication, these individuals should be aware of the various problems facing the Corporation. This knowledge, coupled with their searching into new areas of learning, should from time to time yield inventions or discoveries along lines which might be of use within the Corporation. As we are all aware, inventions are difficult things to come by and cannot be sought directly as such. They can perhaps best be achieved by establishing the proper atmosphere for work by searching minds which are properly loaded with an impedance of known problems needing solutions. Such inventions or discoveries, depending on their particular nature, might well be the starting point or spark to fire up a new program in the applied research group. This then, is another objective of the fundamental physical sciences group.

A third objective is that of specialized but competent advice to management. Such a group as I am describing should have as one of its objectives the recruiting or development of individuals of such stature and ability that they will naturally be sought by management for advice within their particular fields. Many of the important decisions of management in work like ours are highly technical in nature. Since they deal with the future, however, they are not based on cold, statistically analyzed facts, but rather on scientific judgment. It is obviously important that this scientific judgment be formulated by individuals eminently qualified in the field concerned.

A fourth objective of this program is to contribute our fair share to the general fund of scientific knowledge and to the advancement of this fund. To a large extent the Corporation has worked to date by applying to the weapons ordnance business fundamental knowledge which has been acquired elsewhere. If the country is to maintain its lead in the technological weapons race, we must as a nation reach an equilibrium condition where the advances in fundamental technical knowledge balance the rate at which applications can be made to new weapons designs. We feel here that the Corporation has an obligation to make its proportionate contribution to this advance in the fundamental fields. To put this in a different light, we feel that when we go to visit other laboratories, it should be on an exchange basis rather than on a "picking of their brains" sort of basis. This means that we must develop or recruit individuals who stand on equal footing with the others in their field in science.

The fifth objective is a restatement of the first four. The objective is to utilize fully the world of science as it may be applied to the weapons development programs in Sandia Corporation. To make sure that

MAR 1 8 1957

we as a corporation are aware of those advances which may be useful in our work, we must have on our own staff research scientists who themselves are contributing to this advance.

The sixth and last objective is that of establishing a rallying point for recruiting and maintaining on our staff the type of individuals required in a vigorous research organization. I believe that such a program or group as I am trying to describe is strongly appealing to research-minded individuals in physics, physical chemistry, electrical engineering, and engineering mechanics. As has been well publicized, there is a shortage of qualified people in these fields. I believe, however, that the advantages in recruiting a strong staff will extend beyond this group itself. I believe that there are many individuals who themselves prefer to work on applications of new knowledge, but who, nevertheless, wish to be closely associated with individuals working in more fundamental areas. In addition to this, it should be an objective of this group to establish to some extent the stature of Sandia as a laboratory. Also, there is an opportunity to establish a espirit d'corps which could be sparked by such a group as this, but which might well extend throughout the research organization and into other parts of the laboratory. In my opinion there is no question but that espirit d'corps is important in holding well-qualified people on the staff.

esprit de corps

2 CONFIGURATION

There are some characteristics of this group which must be defined, and I lump them under the term "configuration"

First, there is the matter of organization in a formal sense. I believe that it is important that such a group be distinguished and, in a sense, protected by an organizational separation from the remainder of the Corporation. Such a group should be an organizational entity so that it is clear both to those within and without the group that this is a set of persons whose primary goal or primary purpose is that of fundamental research.

This brings me to the type of personnel who must be recruited for such a group. They will be comprised of those holding Ph.D.'s in appropriate disciplines, college graduates with lower degrees, and a suitable number of technical assistants. Those individuals who will determine the success or failure of this group, however, will generally be the ones with Ph.D.'s or equivalent talents and interests. It is these individuals who will supply the real initiative and creativeness for the entire group. We must seek out and select those candidates who have the combination of ability, drive, enthusiasm, and interest in research problems. We must search for those individuals who wish to make "research" a career and then give them the proper opportunity to make a success of this career. Generally, such individuals are found by looking at those people who hold Ph.D.'s in physics, physical chemistry, or electrical engineering. In addition, we should make an attempt to recruit some persons who have gone on to post-doctoral research training. Since we are trying to start such a program, pretty much from scratch, we should also look for those individuals who have had active and successful experience elsewhere but who now find their environment changing to a point where opportunity for research is dwindling with their present employer. Such individuals, of course, are hard to find and attract, but on the other hand would be of great value and benefit to such a program.

In addition to a properly protective organization and a staff of properly qualified personnel, I believe that we must establish a proper atmosphere--one which is conducive to effective research work. Atmosphere, of course, is the sum total of many contributing factors. Perhaps the most important factor is an explicit and continuing expression of desire on the part of management for this type of fundamental research. Research people are very gifted and talented along certain lines but after all, they are human and need continual reassurance that they are doing an important job where they are. A natural part of this reassurance of the value of the activity is an establishment of technical objectives which I will come to in a minute. I believe that I would list, next in importance, the freedom of choice on the part of the individual as to the particular problem or program which he will attack. This freedom of choice, of course, is within boundary conditions established by the management of this group in order to channel efforts in those directions which are believed to be most useful to the Corporation. Another factor which is certainly important in establishing the proper atmosphere is that of no time scales and no schedules for these types of programs. Particularly in a place like Sandia Corporation where there is so much emphasis on fast time scales, we must make a special effort to isolate these individuals from the feeling that certain results must be achieved by certain times. As a part of this same problem we must be very careful to avoid the feeling that only success, by way of inventions or discoveries, is rewarded by management in terms of higher salary or standing within the group. Other factors which are important are the provision of the proper types of space and facility, the proper equipment, and what is possibly more difficult to achieve, the proper level of support activities in a business and trade kind of sense in order that the research scientists may give undivided attention to technology and be relieved of worries of an administrative or a business nature. Also, I believe, that we should attempt to achieve the atmosphere of interchange of knowledge as evidenced by local seminars, attendance at scientific meetings, and informal interchange of information with individuals at other laboratories or universities.

CHOICE OF FIELDS

My statements, up to now, have been of a rather general nature. I would like now to describe how we have chosen particular fields for endeavor from among all those available within the physical sciences. This is certainly a most important matter. It establishes the guide lines within which the individual scientists will work. The choice of these guide lines is crucial, for if they are wrong, then even the best of research individuals cannot make effective contributions to the Corporation. The choice of technical objectives must be subjected to continual review as the technology changes and as Corporation responsibility changes.

In order to establish initial guide lines, we have made an informal survey of the Corporation activities as they have been in the past and as they are now and as we predict them to be within the foreseeable future. We have tried to look at the large number and wide variety of specific development problems and from these find a kind of set of least common denominators. These are a set of fields or disciplines or sciences which are the underlying basis for the solution of many practical development problems. By this kind of reasoning we hope to establish those fields of endeavor which are most closely related to the various activities within the Corporation as of now and within the foreseeable future.

If we wish to stay somewhere near reality, we naturally cannot include all those fields of physical science which might be of interest to someone in the Corporation. Rather we must choose those fields for which we have some reason to expect a probability of success or contribution. In the process of doing this, we have found it helpful to consider research work as falling into one of two classes. In the one class, there may be a field in which Sandia or the AEC has the only active interest. In this particular field, then, we feel that either we do or support research or else it will not be done. As one example of this type, I might point to stability theory for bluff bodies and, as another example, to three-element triggered spark gaps for very high current discharges. In contrast, the second class contains the areas of research in which there is a vast amount of work being done throughout the country. In these cases Sandia, of course, does not presume to accumulate all the knowledge necessary for its problems but rather to make some contribution in the field and in the process become familiar with the entire field. As an example of this, I might point to the transistor art. There is a great deal of work being done at many institutions as you well know, but we feel that Sandia cannot properly assess all this work and interpret it for our own purposes without having our own individuals active in the field

I have here a chart (Figure 1) which summarizes our thinking to the present time about the guide lines for such a program. I will describe for you, in a minute, two programs which we have started in two of these fields. I might point out first the sort of reasoning which has gone into the divisions shown here. In solid state, for example, there are a number of programs in the Corporation to which this relates. Out of a rather large field of solid-state physics we have a particular interest here in the Corporation in the ferroelectric and ferromagnetic materials. The interest in ferroelectrics derives partly from its use as a contact fuzing element, as a voltage source in some external initiator developments, and its general promising capabilities for many ordnance applications. In addition to this, is the interest in the kinds of applications which Frank Neilson described to you earlier. (Ref.) Ferromagnetic and Ferroelectric One-Shot Explosive-Electric Transducers, Technical Memorandum 230-56-51. We believe that the proposals of Neilson are promising enough and sufficiently different in character to warrant support here at a fundamental level. For the present, at least, this is a field which is of somewhat unique interest to Sandia, or at least to the AEC. On the other hand, however, semiconductors as I have mentioned are of high interest in many places in the country. Because of the continuing reduction in the size of atomic weapons, we expect a steady pressure toward the use of semiconductor devices with their small size and low current drain. The particular research investigations, along the lines of semiconductors, however, can best be determined by the particular individuals whom we are able to recruit for this problem. The important thing here, I believe, is that we have on our own staff a man who is familiar with the field of semiconductors and is well qualified to interpret this field to the Corporation.

As another example, let us look at Theoretical Mechanics. We have a continuing and large problem in shock and vibration, those mechanical environments which place severe requirements on our weapon designs. This problem is common to all military designers but has not been satisfactorily solved by any of us. Some preliminary work which was done here a few years ago has indicated that this problem may be susceptible to partial solution by more detailed theoretical interpretation. A problem which, at the present time, is somewhat unique to Sandia is that of resistance to shock impact for extremely high-g acceleration. The trend toward tougher and tougher warheads, which contain only big lumps of material, is placing an extreme load on the individual components which must be designed by Sandia. These components themselves, because of their particular function, may contain many small and possibly complicated parts. The response of these systems to high shocks or high decelerations is not a thing which can be simply analyzed and is certainly poorly handled by static analysis. We believe that a behaviour of materials such as metals and plastics, at very high rates of stress application, would be a very interesting field for research.

I would like to point out that we have a column entitled "theoretical" and that I believe that this column is quite important. One of the characteristics of a university staff, and I think particularly so of those universities which have been most productive, is a balance between theoretical and experimental scientists. The history of science is pretty much a "leapfrog" sort of pattern in which first theory and then experimental evidence seem to get ahead of the other. I believe that it is only by an interchange of individuals concentrating in theory or experimentation that one achieves the most effective output from a given sized group. I believe that the variety of programs which we have listed here should offer a sufficient challenge for most any theoretician

Note also that we have listed a column which is called "experimental analytical techniques". This is listed separately to emphasize the fact that we expect that such a program will contain as an integral part some research on the analytical procedures themselves where these procedures are done by physical measurements. We intend, of course, to make use of what equipment and apparatus as already available within the corporation. We expect, however, that some of the analysis work will be of such an individual and unique character that it will be a research problem within itself and should be handled within the group.

EXAMPLES

As specific examples of the types of programs we are planning, I would like to talk about radiation effects and physical electronics. Let us deal first with radiation effects. The Corporation is interested in the damaging effect which nuclear radiation may have on materials or components, because of possible vulnerability to enemy counterweapons and, at a time somewhat farther in the future, the damage which may be caused by the radiation environment of a nuclear power plant in an aircraft or a nuclear rocket. This interest has been formalized in a letter which Gen. Hertford from AEC has written to AFSWP in which he states that Sandia Corporation will have the primary responsibility for the AEC in the study of radiation effects on weapons and their components. You have been briefed, I understand, on the comprehensive engineering program which we plan at Sandia to prove out the capability of our weapon designs against radiation. This program will be centered about the reactor facility which is now a part of our budget request.

We here in Research feel that this engineering program should be balanced by a more fundamental program in which individuals on our staff attempt to gain a better understanding of the fundamental processes which are involved in the interaction of nuclear radiation with matter. To get started in this program we have chosen four fields for investigation. First of all are the semiconductors. These are the most sensitive devices to radiation damage and therefore are of most critical interest. We have faith that by one means or another the intolerance of solid-state devices to irradiation damage will be solved as time goes on. Perhaps we will be able to make some contribution to this solution in those areas which are of particular interest to us. We plan to start this program on two levels. On the one hand, we will repeat experiments done elsewhere to establish self-confidence in our techniques and the equipment. At the same time, we will perform experiments in connection with Series Plumbbob to take advantage of the unique source of extremely high rates of neutron exposure.

Second are the polymers and their interaction with radiation. We are fortunate in having on our staff a man who has had experience along these lines at one of the country's major rubber and plastics companies. Polymers are of interest here, of course, for insulation purposes in electrical components and as structural members where low-density material is required.

Third, we plan some work in the area of alkali halides, not so much because of direct application in weapon design, but rather because these materials are relatively simple in structure and there is at least some possibility for theoretical interpretation of the experimental results and potential use in dosimetry.

Fourth, we have already done some preliminary work on the effect of radiation on the ferroelectric materials. This work was done in connection with the Redwing series in the Pacific last year. Because of this start and because of our general interest in the ferroelectrics, we would like to follow this up with further work on the interaction of radiation with the ferroelectric materials. We have hopes that changes here at the crystal structure level may be revealed by external change in the piezo- or ferroelectric properties of these materials.

As the primary experimental facility for this program, we are purchasing a van de Graaff generator and expect to have built a proper building to house this. We have chosen the van de Graaff for its versatility in the types of nuclear particles which it can produce and for its ability to produce particles of one type only and of a known energy or energy spectrum. We believe that this equipment will make a very fine complement to the reactor facility which is planned here. We have also spent a considerable amount of effort and time on the plans for the reactor facility itself. We are anxious to see that these plans, while achieving the primary purpose of providing a test facility, also allow for the effective use of this reactor as a research tool in the study of irradiation damage on materials. To this end we have requested the inclusion of such items as rabbit tubes which go very near the reactor core and even tubes which go inside the boral thermal neutron shield so that we can achieve higher neutron activation on small samples when required. In addition to these facilities, we plan, as I have mentioned, participation in the full-scale tests which are the only source at present of the very high neutron fluxes which might be the final test of our particular designs. As a laboratory substitute for a source of very high fluxes of neutrons, we have considered the use of a Godiva-like critical assembly system which will give neutrons at a very high rate but for a very short duration. Our consideration of this has not progressed beyond the talking stage. We are already convinced, however, that one of the things we must understand is the effect of a rate of exposure upon the damage which may be done. Our primary facility for testing of actual development components will be the reactor in which very high total fluxes can be achieved only by long exposures at moderate flux rates. It is obviously most important to establish whether this kind of a test is fully equivalent to the same total dose delivered in times less than one second.

As a second example of the kind of programs of problems that we propose in a given field, let us look at physical electronics. The Corporation makes extensive use of three-element gaseous discharge tubes in practically all weapon designs, and every weapon containing an implosion warhead depends on exploding wires to initiate its sequence. Many of our weapon designs are now using external neutron sources which are essentially a type of ion tube. In all of these fields, a great deal of empirical work has been done in which various parameters have been correlated with the electrical or energy inputs required.

In the area of exploding wires, George Anderson and Frank Neilson have already done some good work in trying to correlate the physical properties of the wires with their electrical history as they explode. We believe that this type of work is worthwhile in understanding what is going on and that it could be extended to include a study of the interaction between the exploding wire and surrounding PETN. The studies to date have already yielded a sufficiently better understanding of the process involved to allow for a reduction by a factor of ten in the electrical energy required for a detonator to be properly initiated.

Sandia has done or sponsored a great deal of work which has allowed for the design of triggered electrodes and, along somewhat parallel lines, the design of neutron sources. In the one case, we have only a most superficial knowledge of how the triggering spark transfers to the main gap in a trigger electrode switch. In the other case, we have only the poorest understanding of how the source spark actually creates and liberates hydrogen ions into the surrounding atmosphere.

We believe that an investigation into the ion production phenomena might be most rewarding. This type of knowledge may well be overlapping with the work in high temperature. It looks there as though a very high-energy spark gap may well be the most convenient laboratory source of pulsed high-temperature source.

CONCLUSION

These are the first examples of the type of work we would do in fundamental research. We believe that it has direct value to the Corporation and should be supported and expanded.

R. S. Claassen - 5133

RSC:5133:xp

SF 2900-KBS-861

DECLASSIFICATION NOTICE

TO:

1000 V. Narayanamurti
1100 F. L. Vook
0 S. T. Picraux
..20 J. B. Gerardo
1130 G. A. Samara
1140 P. S. Peercy
8000 R. S. Claassen
8024 F. E. Halasz

Date 5/20/87

SENDER: SANDIA NATIONAL LABORATORIES
CLASSIFICATION OFFICE

Check originating address

☐ Department 3180
P.O. BOX 5800
ALBUQUERQUE, NEW MEXICO 87185

☒ Division 8024
P.O. BOX 969
LIVERMORE, CALIFORNIA 94550

DOCUMENT ORIGINATOR: Mark document(s) as Unclassified. Forward copy of this notice to recipients of initial distribution, except the Office of Scientific and Technical Information (formerly TIC), which is handled by Classification and Sensitive Information Review Department 3180 (8024).

RECIPIENT OF FORM: Mark document(s) as Unclassified. If documents have been transferred or copied, send copies of this notice to Transferees/Copyholders.

Complete Document Description and Date	Present Classification Level and Category	New Markings (e.g. Limitations on Distribution)
15 page Document dtd 3/16/57, titled "Introduction." Subject of the doc. was a presentation by M. J. Kelley on 3/16/57 describing the plans for fundamental research at Sandia. An unclassified transmittal letter was attached (dtd 5/31/57) and at that time the above organizations were: Fowler, 5000 Hight, 5100 Merritt, 5110 Bledsoe, 5120 Hansche, 5130 Pope, 5140 Claassen, 5133 The transmittal letter was signed by R. S. Claassen.	CRD	None

eview Requested by R. S. Claassen Org. 8000

eclassification is based on topics 502, 506, 531 of CG-W-5; 463 of CG-WI-1

or for other reasons:

classification action is authorized by the undersigned, who has been granted the authority to declassify by the DOE.

x RS Claassen 8000 5/20/87
Signature of Authorized Declassifier Org. Date

e custodian of the document described herein is authorized to remove, cancel, or otherwise void the classified markings from the document. ch markings may be removed only when the correspondence of this notice to the document has been verified by two persons, who must insure at the document concerned identically fits the description provided herein. Otherwise the markings may not be removed. If there is any doubt re- rding the identity of the document to which this notice applies, the recipient should contact the originator of the notice for further information. e persons who remove the markings and validate that action shall mark the document as having been declassified, identify this notice as their thority for doing so, and sign and date the action on the document. If a person who receives this notice has given the document or copies there- to others, this notice should also be forwarded to such other custodians.

Physical Sciences Research at Sandia

Source: richard S. Claassen Collection Frank Hudson Collection - Deerived from Hudson's initial plan for Fundamental Research at Sandia

	SOLID STATE	RADIATION EFFECTS	COMBUSTION PROCESSES	PHYSICAL ELECTRONICS	HYDRO- MAGNETICS
PROGRAMS	Semiconductors Ferroelectrics Ferromagnetics	Semiconductors Polymers, Ionic Crystals	Propellants Heat Powders Explosives	Gaseous Discharge Ion Production Exploding Wires	Impluse Tube RF Moving Field Machine
TYPICAL PROBLEMS	Electronic vs. Ionic Nature of Ferroelectricity Relation of Surface Condition to Electrical Properties High Energy Density Properties of Ferroelectrics and Ferromagnetics	Damage Mechanisms in Semiconductors Structural Changes Induced in Polymers Color Centers in Alkali Halides Rate Effects in Neutron Doses	Heat Powder Burning Parameters Study of Transient Gas Products in Explosives Relationship of Structure to Propellant Burning	Energy Propagation in Gaseous Discharge Mechanisms of Ion Production Energy Production and Transfer Related to Exploding Wires	Magnetic Coupling Separation of Ohmic Heating and Magnetic Acceleration Magnetic Structure of Shocks
SANDIA INTEREST	Transistors Diodes Voltage Sources	Vulnerability Radiation Environment	Exploding Switches Thermal Batteries Detonators Propellant Activated Devices	Spark Gaps Switching Tubes Detonators Zipper Sherwood	Sherwood, Fireball Re-Entry High-Temperature Sources

Physical Sciences Research at Sandia

Source: richard S. Claassen Collection Frank Hudson Collection - Deerived from Hudson's initial plan for Fundamental Research at Sandia

HIGH TEMPERATURE	THEORETICAL MECHANICS	GEOPHYSICS	THEORETICAL	ANALYTICAL
Thermal Shock Energy Transfer Material Properties Ablation	Dynamic Similitude Stress-Strain-Time Relationship	Upper Atmosphere Physics		
Effect of Thermal Transients on Surfaces Grain Boundaries Near Melting Ablation in Controlled Atmosphere	Scaling Laws in Dynamic Studies Molecular Structure-Mechanical Property Correlation Strain Produced by Short Duration Stress	Energy Transfer at High Altitudes Altitude Dependence of Various Parameters	Theoretical Physics Support of Other's Research Programs Independent Programs	Development of special Techniques for Detection of Physical Changes and Interpretation of Secondary Indications of Such Changes in Support of Other Research Programs
Fireball Re-Entry Sherwood Rover	Shock & Vibration Model Studies of Warhead Design	High Altitude Systems	Research Support	Research Support